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Factors Influencing Postsecondary STEM Students' Views of the Public Communication of an Emergent Technology: A Cross-National Study from Five Universities

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Abstract: Recent efforts in the science education community have highlighted the need to integrate research and theory from science communication research into more general science education scholarship. These synthesized research perspectives are relatively novel, but serve an important need to better understand the impact that the advent of rapidly emerging technologies have upon a new generation of scientists and engineers as well as their formal communication with engaged citizenry. This cross-national study examined postsecondary science and engineering students' (*n* = 254 from five countries: Austria, Finland, France, Israel, United States) perspectives on the role of science communication in their own formal science and engineering education. More broadly, we examined participants' understanding of their perceived responsibilities of communicating science and engineering to the general public when an issue contains complex social and ethical implications (SEI). The study is contextualized in the emergent technology of nanotechnology for which SEI are of particular concern and for which the general public often perceives conflicting risks and benefits. Findings indicate that student participants' hold similar views on the need for their own training in communication as future scientists and engineers. When asked about the role that ethics and risk perception plays in research, development, and public communication of nanotechnology, participants demonstrate similar trajectories of perspectives but that are often anchored in very different levels of beginning concern. Results are discussed in the context of considerations for science communication training with in formal science education curricula globally.

Keywords: Science communication, Cross-National Study, Postsecondary, Emergent Technology, Nanotechnology

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Quality formal science and engineering education are foundational for, “(r)eaffirming and strengthening… scientific discovery and technological innovation (and are) essential to meeting the challenges of this century” (PCAST, 2012) worldwide. Policy discourse in science education often focuses on promoting content acquisition at the expense of contextual considerations, yet it is clear that scientific research and development does not occur in a vacuum but within a broader society (Zeidler, 2015). As such, introduction of technological innovations in the public sphere are often accompanied by significant ethical questions as well as associated concerns about the risks and benefits to humans and the environment (Sandler, 2009). Recognizing this, the science education community has developed various curricula that harness the contextualized nature of science with the goal of educating a scientifically literate public to engage in discourse at the intersection of the social and the scientific (Zeidler, Sadler, Simmons, & Howe, 2005). What is far less apparent is how future scientists and engineers are appropriately educated to engage with the social dimensions of science in both their practice and when communicating their work to a non-specialized audience or whether they should be doing this at all.

With the rapid development of technologies there is a growing need to educate future scientists in the fundamental science content that drives advancement in these areas as well as how to communicate about advancements with the public sphere (Guston & Sarewitz, 2002). Within a complex social environment, practicing scientists have a growing challenge to communicate scientific developments to a new generation of scientifically (il)literate citizens who can participate in public decision-making as well as act as informed consumers (Feinstein, 2015). And yet, in general, research has demonstrated that scientists receive little education in the field of public science communication during their formal schooling especially as it relates to social impacts of science and technology (Baram-Tsabari & Lewenstein, 2013). More needs to be known about how future scientists and engineers are trained and view their roles in science communication in order to continue to develop effective education programs in this discipline.

Countries like the United Kingdom have proposed integrated training in science communication for scientists and engineers at the postsecondary or graduate level (Baram-Tsabari & Lewenstein, 2013; Edmondston & Dawson, 2013; Edmonston, Dawson, & Schibeci, 2010a) to promote effective communication in their fields. However, there is little research into the most effective means to educate scientists to be competent science communicators to the general public (there is a large body of literature examining educating scientists about how to communicate the technical aspects of their work primarily to other scientists). In addition, there is little work into what scientists (and future scientists) believe are the important aspects for them to be able to communicate to the general public.

To address the aforementioned deficiencies, this study explored how postsecondary students in science and engineering (future scientists and engineers) fields at five cross-national universities perceived their preparation as science communicators. Beyond this, we were also interested in also exploring how they perceived the risks and benefits of new technological developments (a key socially-relevant science issue, see Authors, 2010) as potential socially-mediated predictors of their perceptions of responsibilities to communicate with others about the social impacts of new technological developments. The study was prompted by recent efforts in the science education community that have recognized the need to integrate research and theory from science communication into education scholarship (Baram-Tsabari & Osborne, 2015).

To situate the research we first briefly review the current literature on the state of formal postsecondary science communication training as well as student and instructor views of this training by discussing how the science education literature has attempted to answer the following questions: *Who should be responsible for education scientists and engineers in science communication?*; *What skills should be required for scientists and engineers to effectively communicate with the general public?* and *Do science and engineering instructors and students perceive science communication training as relevant?*

Views of Science Communication Education

Responsibility for Educating Scientists and Engineers

Although there is a need to prepare future citizens about the social and ethical issues (SEI) that arise with new developments in science and engineering, it is less clear who is responsible for educating the next generation of scientists to participate in the process of science communication. Arguments can be made for both formal science educators as well as professional science communicators being synergistically responsible for educating future scientist in the skills required to be effective science communicators (Feinstein, 2015). These two groups (science educators and science communicators), however, have largely worked independently of one another both in science communication research and educational practice. Education and engagement of the public regarding science and technology has historically been the venue of science communicators. We define professional science communicators primarily as academics who study and practice presenting science-related topics to non-experts.

Science communicators disseminate science knowledge as well as engage individuals in the current public dialogue surrounding science and technology while science educators have limited themselves to formal classroom environments (Baram-Tsabari & Osborne, 2015). Yet, neither of these groups have the primary responsibility for educating future scientists especially in post-secondary settings.

Could it be that practicing scientists and engineers take on the responsibility of science communication training for future colleagues in their field? For scientists and engineers it appears many of them do not see themselves as responsible for training postsecondary students in science in communication, especially students who are often unmotivated or unwilling to participate (Edmonston, et al., 2010a; Yeoman, James & Bowater, 2011). Despite their apparent lack of interest in learning about science communication skills, postsecondary students in the Edmondston et al., (2010a) study still claimed that biotechnologists (right behind professional science communicators) should be responsible for a large portion of communicating both the technical as well as SEI aspects of biotechnology. In a more recent study, Besley, Dudo, and Storksdieck (2015) found that scientists are willing to involve themselves in some communication training but are not invested in all it would require to become competent in public science communication relationships. Not surprisingly, in contrast to views of scientists, *science communicators* in postsecondary academic contexts almost universally think that science communication training is critical for scientists (Besley & Tanner, 2011).

Skills Required for Effective Science Communication

Scientists and engineers also disagree about what is needed of effective science communicators. Most notably one science communicator thought of the most important learning outcomes for students being trained in science was that they would be able to engage the public, be sensitive to community concerns, and better contribute to their community (Besley & Tanner, 2011). This perspective was in contrast to the scientists who primarily looked at the ways that the individual students (and not the public or larger community) would benefit from this training (Edmonston & Dawson, 2013). Others in science communication noted that communicating with the public would assist scientists in better reflecting on the aims and outcomes of their research. Science communicators argue that without preparation many scientists who do engage with the public will maintain a deficit model of thinking with the assumption that they can promote science literacy through just delivering fundamental content about science without being sensitive to community engagement and issues related to SEI (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008; Besley & Tanner, 2011).

When postsecondary students were asked to describe the skills they believed they will need as scientists, students reported that the technical aspects of communication (science facts and theories, technical skills, communicating with other scientists, etc.) were especially important (Edmondston et al., 2010a). Other studies have reported that the skills that a scientist or engineer would need to communicate science to the public include content knowledge, the ability to organize knowledge, clarity and language of readability of written text, communication style, the appropriate use of analogy in explaining complex topics, narrative structure, and dialogue (while respecting multiple worldviews) (Baram-Tsabari & Lewenstein, 2013). One of the most interesting results of the aforementioned study is the potential conflict that might arise in learning to communicate to a *scientific audience* versus learning to communicate to a *lay audience* and how student scientists/engineers might have to disregard some technical information to effectively communicate to the public.

When students are taught to communicate science to the general public, there is evidence that students gain knowledge and confidence in the field (Webb et al., 2012; Whittington, Pellock, Cunningham, & Cox, 2014). A study of early career biotechnologists found that these individuals felt prepared to communicate the technical aspects of biotechnology but some felt unsure about communicating the social and ethical implications of their work (Edmondston et al., 2010b). This study found that the confidence communicating science that these early career scientists exhibited did not result from their formal schooling but was a consequence of informal experiences (coaching, internships, etc.) (Edmondston et al., 2010b). Besley et al., (2015) highlighted skills required to be an effective science communicator in a recent article that included: 1) making science messages understandable, 2) building trust and credibility, 3) demonstrating listening to public views, 4) demonstrating value of public views, and 5) framing messages to resonate with public values.

Importance of Science Communication Education

Understanding how science and engineering instructors as well as their students perceive the importance of science communication to their professional development is also a critical component of professional career development. Studies have examined postsecondary science faculty views of whether science communication is important for scientists. In a study related to their work with biotechnology communication, Edmondston, Dawson, and Schibeci (2010b) asked both science communication and science faculty their views of science training for biotechnology students. Science faculty provided conflicting results regarding the importance of science communication for themselves and their students. On one hand they supported the importance of students acquiring skills in communicating science to non-scientists, and at the same time they questioned exactly where education in science communication would fit in the larger curriculum (Edmondston & Dawson, 2013).

To most faculty, what was of greater importance is being able to communicate science to other scientists (Edmonston et al., 2010b). One particularly resistant professor stated, “Most people just aren’t good at communication so you’re teaching them something that most of them are not going to be good at, or don’t even want to do” (Edmondston & Dawson, 2013, p. 8). This was contrasted by faculty who felt science communication training would give students a broader understanding of the role of communicating science to the general public. Other faculty felt that scientists had no responsibility in communicating to the general public and that this role should be left to professional science communicators only (Edmondston & Dawson, 2013).

Students perceive that communicating SEI to the general public is significantly more important than communicating the technical aspects of science and technology because the technical aspects would be too difficult for the citizenry to comprehend (Edmondston et al., 2010a). Whether students perceive the inherent conflict of their reported need not to engage in training in science communication while simultaneously noting that they will one day be responsible for just that is unclear. Results could be skewed by the fact that students still seem to perceive that their communication to the general public should flow through an intermediary (such as the media or a science communicator). This also demonstrates the challenge that SEI presents when considering education in science communication for scientists and engineers. The next section reviews these challenges and provides the science and engineering context for the current study, nanotechnology.

Communication of Social and Ethical Issues: The Case of Nanotechnology

It is increasingly likely that developments in science and technology will impact the average citizen in the coming decades due to the emergence of new research fields (NSF/DOC, 2002) such as nanotechnology, biotechnology, information technology and cognitive science. In addition, many traditional fields of science and engineering cross traditional disciplinary boundaries, only compounding the complexity of technological development for the public sphere. Faced with this complexity, attitudes of the general public towards research and development in science and technology fields remain generally positive (Miller, 2004). Positive attitudes, typically supported by perceptions of the value of science for individual quality of life and as a key component of economic prosperity, are counterbalanced by public concerns (Hisschemöller & Midden, 1999). Uncertainty about the potential risks these new technologies might present to themselves and the environment often drive these concerns

(Savadori et al., 2004; Siegrist, 2010; Sjoberg, 2002). Trust (or a lack thereof) in government officials to appropriately and fairly regulate applications has also been shown to be a key component in how individuals engage with emerging technologies (Resnick, 2011).

As with most technological developments, the public frequently has positive attitudes toward the field and see value in its development (Bainbridge, 2002; Lin, Lin, & Wu, 2013; Scheufele et al., 2009). These favourable attitudes are tempered by reactions to resist nanotechnology development on the grounds of potential risks to such things as human health and the environment, in addition to other concerns (Authors, 2009; Cacciatore, Scheufele, & Corley, 2011; Sandler, 2009). This is further escalated by a general distrust of the ability of governments to regulate these developments in the face of uncertainty (Macoubrie, 2006). This leads to individuals often bringing conflicting feelings of hope and fear to the discourse of advancements in nanotechnology (Sandler, 2009). These characteristics of nanotechnology make it particularly appropriate as a Social and Ethical Issue context for the present study and highlight its importance as a mediating factor in considering perceptions of the role that scientist and engineers might play in science communication.

We have chosen to contextualize our study in nanotechnology because it is a field in which new questions about how to educate current and future generations about the potential benefits, the possible risks, and the ethical implications of advancements continue (Authors, 2015; Robinson, 2004) and therefore has many associated SEI. Perhaps as never before scientists and engineers can tinker with the building blocks of nature, raising questions of “playing god” as well as other critical ethical considerations (Sandler, 2009). These scientific advancements push science educators to find new ways to prepare the next generation of scientists and engineers to be able to communicate not only to each other but also to those who are the consumers of science. Nanotechnology is characterized as the design and manipulation of materials at the atomic and molecular scales (more precisely the scale 10^{-9} meters). The term nanotechnology can be confusing as it is actually a collective term for a diversity of research methodologies and applications that intersect the fields of physics, chemistry, and biology.

Findings from research in school contexts show that both students’ and teachers’ knowledge of nanotechnology is generally low (Authors, 2010; Authors, 2014; Ekli & Sahin, 2010). These results align with findings on studies conducted in the general public. Much of the knowledge regarding nanotechnology is not coming from credited informal or formal educational sources and it is not a great predictor of attitudes and perceptions of risk (Authors, 2010; Elki & Sahin, 2010). One of the few studies of student attitudes about nanotechnology found that even after instruction there was no significant change attitudes (Englander & Kim, 2011). Researchers have also found that there are numerous challenges in helping students discern the complexity inherent in understanding the risks of nanotechnology (Simonneaux, Panissal, & Brossais, 2013). Perceptions of risk and benefits are not polar concepts (i.e. high risk does not necessarily imply low benefit and vice versa). Participants in educational contexts may hold simultaneous beliefs that nanotechnology applications have high potential benefits *and* high potential risks and that these factors have to be weighed independently in order to assess their relative value to society (Authors, in press; Ekli & Sahin, 2010). For example, many medical applications of nanotechnology are perceived as highly risky to an individual's health, but also potentially highly beneficial (Authors, 2010; Elki & Sahin, 2010; Nerlich, Clarke, & Ulph, 2007).

At this point nanoethics is a field that considers the *perceived* risks since the technical and research-based risks are not yet fully known (Moor & Weckert, 2004) but may be informed by ethical concerns of previous emerging technologies (Grunwald, 2005). Concerns about nanoethics are bound to perceptions of the risks and benefits and the associated views of which nanotechnologies should rightfully (or not) be developed. Nanotechnology is such a new field that it offers a unique opportunity for researchers to examine how ethical views of technology develop for the next generation of scientists and engineers. Furthermore, for one of the first times in human history we have the opportunity to shape discourse about the development of nanotechnologies, enlarging the conversation about social responsibility and sustainability (Johnston, McGregor, & Taylor, 2010) and potentially avoid the pitfalls that have accompanied the use of other emergent technologies such as genetically-modified foods (Brownsword, 2009).

Research Questions

The study reported here explored postsecondary science and engineering students' views on science communication of an emergent technology from a cross-national perspective by looking convenience samples from five universities in five different countries. The study is a cross-cultural, cross-sectional survey study. A special focus was given to the question whether postsecondary students in different European countries and the US arrive at the same views on nanotechnology applications as a model emergent technology (see below). In addition, the international samples allow for an initial examination of data across different geographical regions. Furthermore, we examined whether or not students' personal views of the social and ethical aspects of these technologies provided predicted views of the SEI and communication views towards these technologies. Due to the nature of this study, statistical generalizability beyond the scope of the sample contexts is impossible. As such we hope to answer the following research questions as part of an exploratory analysis that will provide a framework for theoretical generalizability in future studies.

1. What are this sample of postsecondary students' views about their responsibilities for the public communication of nanotechnology related to social/ethical issues?

2. What are this sample of postsecondary students' views about whether it is socially/ethically justifiable to further develop nanotechnology applications?

3. How do views of social/ethical issues contribute to participants' assessment of whether it is ethically justifiable to further develop a nanotechnology application?

Methods

Participants

Participants (*n* = 254) in this study were postsecondary science and engineering students selected as a convenience sample from international universities including Austria (*n* = 63), Finland (*n* = 35), France (*n* = 30), Israel (*n* = 34), and the United States (*n* = 92). The sample was made up of 116 females (45.7%) and 138 males (54.3%) with an age range of 18 to 55 years (M = 23.69, SD = 4.04) with some of the older students being distinct age outliers. Participants were students in sciences and engineering fields that included engineering (19.69%), biology/biochemistry (38.19%), chemistry (9.06%), physics (22.44%), pharmaceutics (4.33%), clinical lab science (1.57%), and mathematics (4.72%). There were no significant differences between major fields of study in the outcome variables. Only 13.0% of participants reported having received training in how to communicate the technical aspects of science to non-scientists. Similarly only 5.5% of participants reported that they had had preparation in how to communicate the social and ethical implications of nanotechnology research to non-scientists.

It is important to note that this study does not represent a comprehensive or generalizable view of the perceptions of the general public in the countries studied or of postsecondary students as a whole. Samples represent a glimpse into a sub-set of training to be scientists and engineers in each of these countries and are contextually bound. As such this study is exploratory in nature and will answer the research questions within a limited context.

Measures

A survey was used to examine student views of science communication and the social and ethical impacts of nanotechnology. The first set of items was adapted from the study by Edmondston et al. (2010a) regarding students' *views of science communication and science communication training*. The second set of items was adapted from Siegrist et al. (2007) and regards students' *risk perception of nanotechnology applications*.

Views of Science Communication and Science Communication Training. Participants were asked a number of items regarding their views of science communication and science communication preparation for scientists. These items included statements on governments' responsibility to communicate technical aspects of nanotechnology research, as well as statements about nanotechnologists' responsibility to communicate aspects of their research. Furthermore, students rated the importance of nanotechnology applications for the development of the economy (items for this instrument can be viewed along with the results in Table 2 and align closely with the instrument used by Edmonston et al., 2010a).

Risk Perception of Nanotechnology Applications. The survey includes 20 nanotechnology applications that were intended to be representative of a variety of applications currently in use that are constructed using nanoscience and technology. The survey also included three "control" applications (asbestos use, genetically-modified tomatoes, and cellular phones) to allow for analysis of whether levels of perceptions of risk were characteristic of the individual participant or a characteristic of the specific nanotechnology application (i.e. did an individual report high risk perception on the nanotechnology items because they were a naturally "risk adverse" individual?). Multiple nanotechnology applications and not just nanotechnology in general was utilized because previous studies have demonstrated that students do not associate individual applications with the same amount of risk (Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007).

The instrument has been used in different studies and is based on a widely used approach of assessing risk (Siegrist et al., 2007; Fischoff et al., 1978). These items are based on the psychometric paradigm of risk that hypothesizes that perceptions of risk can be mapped along different facets of a particular technological hazard. There are a variety of frameworks that examine how individuals conceptualize and perceive the risks related to various hazards. Building on these frameworks in future studies will help inform the body of literature to better understand risk perception from a developmental perspective as students transition from the classroom to the public domain. The psychometric paradigm of risk perception is one such framework. This paradigm proposes that perceptions of hazards are not dependent on the individual, but on the characteristics or facets of the hazard itself. This theory posits that a "personality profile" of the hazard can be created by examining the degree to which individuals perceive the risks and benefits of certain aspects of that hazard (for a full discussion of this theory, see

Slovic, 1987). Once this hazard profile is created it can then be used to drive policy as well as comparison/contrast with other technologies.

In the comprehensive survey instrument, each nanotechnology application is followed by a brief phrase that indicated the way in which nanotechnology was being used in this particular application. After reading the description participants assessed their perceptions of each individual application along eight facets of risk on Likert-type rating-scales from 1 to 5. All the facets below align with Slovic's (1987) characterizations of hazard attributes that might be critical in defining perceptions of risk:

1. *Probability of health damage* (1 = very improbable; 5 = very probable)
2. *Worries about risk* (1 = not worried; 5 = very worried)
3. *Voluntariness of risk* (1 = voluntary; 5 = involuntary)
4. *Knowledge of risk to those who are exposed* (1 = known precisely; 5 = not known)
5. *Adverse health effects* (1 = not at all; 5 = very strong)
6. *Control over risk* (1 = controllable; 5 = uncontrollable)
7. *Trust in governmental agencies responsible for protecting people's health* (1 = much trust; 5 = no trust)
8. *Ethically justifiability to further develop the application* (1 = absolutely justifiable; 5 = not justifiable)

In the present research, the eighth characteristic (ethical justifiability) was of particular interest. The psychometric properties of the 20 nanotechnology items belonging to the eighth dimension of ethical justifiability were analyzed by a principle component factor analysis. It yielded a two-factor solution (Table 1). The item ammunition loaded on a single independent factor and was removed from further analysis. Three items loaded about equally high on both factors (lightweight building materials, sunscreen, surface impregnation) and were therefore excluded from further analyses. The two-factor solution in the reduced model explained 50% of the variance in the data.

[INSERT TABLE 1 ABOUT HERE]

Factor 1 included eight nanotechnology applications that might be considered commonplace and was called "innocuous applications" (in contrast to Factor 2). Factor 2 included eight applications that might have direct contact with individual internal or external body surfaces and was named "direct contact applications." These results align with similar studies that show that individuals differentiate perceptions of risk and benefits along a continuum of what they feel might potentially enter or contact their bodies (Authors, 2010). Cronbach's α for the two factors was considered very appropriate with α = .830 and α = .864 respectively. Furthermore, a confirmatory factor analysis was carried out, to verify the adequacy of the two-factor-solution.

A composite score was calculated for each of the two factors. In order to obtain participants' assessment on a factor, the scores on all items belonging to one factor were averaged to create a single combinatorial variable. This two-factor solution was also to be used as a basis for the calculation of two composite scores for the facets 1 to 7. Before applying this solution to the other seven facets, their internal consistency was assessed. Cronbach's α for the two scales of the seven facets were between .728 and .834 (with one exception of α = .624). These analyses speak for a statistical acceptability of a two-factorial structure of all eight facets of risk assessment. Therefore, for each facet one composite score was calculated as the mean of the items belonging to the first factor (innocuous applications) and another one as the mean of the items belonging to the second factor (direct contact applications) along each facet. Factoring these items allowed us to reduce the number of nanotechnology applications to be used in the below analysis.

Analysis and Results

Research Question 1

To address research question 1, a multivariate analysis of variance (MANOVA) with the five individual countries (Austria, Finland, France, Israel, and United States) as the between-subjects factor was carried out for the items on students' perceptions toward nanotechnology (see list of items in Table 2 below). Results showed a statistically significant effect of country of origin on student perceptions about the responsibility of communicating the implications of nanotechnology research, $F(16, 978) = 17.88$, $p \leq .01$, $\eta^2 = .23$. The subsequent analyses address participant perceptions about *who* should be responsible for communicating about nanotechnology (the government or nanotechnologists) and *what aspects* of nanotechnology should be communicated (technical aspects, research implications, and social and ethical implications).

[INSERT TABLE 2 ABOUT HERE]

The subsequently performed univariate F-test for the item regarding the *government's* responsibility for communicating *technical* aspects of nanotechnology research showed significant differences between the countries, $F(4) = 11.12$, $p \leq .01$, $\eta^2 = .15$. Tamhane post-hoc tests showed significant differences between the United States, Austria, Finland and Israel, with United States participants more likely to report that the government was responsible for communicating the technical aspects of nanotechnology research to non-scientists (all reported differences significant at $p \leq .01$).

The univariate F-test for the item that asked about the responsibility of *nanotechnologists* to communicate *technical* aspects with non-scientists showed significant differences between the countries, $F(4) = 31.04$, $p \leq .01$, $\eta^2 = .33$. Tamhane post-tests showed that Austria, Finland, France, and Israel differed significantly from the United States (all reported differences significant at $p \leq .01$). Participants from these countries (Austria, Finland, France, and Israel) attribute more responsibility to nanotechnologists to communicate the technical aspects of their research than the United States sample.

The univariate F-test for the item that asked about the responsibility of *nanotechnologists* to communicate the *social and ethical implications* of their research with non-scientists was also significant, $F(4) = 49.47$, $p \leq .01$, $\eta^2 = .44$. Tamhane post-tests showed that Austria, Finland, France, and Isreal differed significantly from the United States in attributing more responsibility to nanotechnologists to communicate the social and ethical implications of their research (all reported differences signficant at $p \leq .01$).

The univariate F-test for the item that asked about the responsibility of *nanotechnologists* to communicate *about their research and its implications* with non-scientists also showed significant differences by country, $F(4) = 18.16$, $p \leq .01$, $\eta^2 = .23$. Post-hoc tests showed that Austria, Finland, France, and Israel differed significantly from the United States in attributing more responsibility to nanotechnologists to communicate research and the implications to non-scientists (all reported differences significant at $p \leq .01$).

In summary, participants from the USA believed more strongly than participants from Austria, Finland and Israel that the government should be responsible for communicating the technical aspects of nanotechnology research with non-scientists. In comparison, US participants attributed less responsibility than participants from Austria, Finland, France, and Israel to nanotechnologists for communicating technical or social aspects of nanotechnology research to non-scientists.

Research Question 2

To answer research question 2, a multivariate analysis of variance was calculated for the composite scores for both nanotechnology application factors on the ethical justifiability of the various nanotechnology applications. The means and standard deviations for the two factor variables are shown in Table 3. This analysis examined cultural differences in participants SEI perceptions of nanotechnology applications that are hypothesized to impact their views of appropriate communication strategies.

[INSERT TABLE 3 ABOUT HERE]

The MANOVA with the between-subjects factor "country" showed a significant effect, $F(8, 494) = 20.36$, $p \leq .01$, $\eta^2 = .25$. Subsequently performed univariate F-tests confirmed significant differences for both factors on the facet of ethical justifiability (innocuous applications: $F(4) = 13.82$, $p < .01$, $\eta^2 = .30$; direct contact applications: $F(4) = 17.02$, $p < .01$, $\eta^2 = .31$).

Tamhane post-hoc tests for the factor "innocuous applications" showed that Austria and Finland differed significantly from France and the USA (all reported differences signficant at $p \leq .01$) and France differed from all others including Israel. This means that participants from the USA and France regarded it as less justifiable to further develop nanotechnology applications than participants from Austria and Finland. Participants from the USA and France were most critical towards further development of nanotechnology applications. Furthermore, Israel was inbetween the USA and Austria and Finnland, not differing from either of those.

Tamhane post-hoc tests for the factor "direct contact applications" show that the USA and France are more critical towards the ethical justifiability of further develoment than Austria, Finland and Israel (all *p*s $\leq .05$). Within the latter group, Austrian subjects were more critical than Finnish subjects, but neither Austrian nor Finnish subjects differed from Israeli subjects.

Research Question 3

Research question 3 was answered in the following way. As described in the measures section, the participants rated each nanotechnology application on eight facets of risk (as hypothesized by the psychometric paradigm of risk), among them the ethical justifiability of further developing an application. The perceptions of the first seven facets (e.g., probability of health damage, worries about risk) were explored to see if these facets of risk predict the perceptions of ethical justifiability of further development of nanotechnology applications. Two regression analyes were carried out, one for each composite factor score. Predictor variables were the composite scores for the seven facets (one composite score for each factor, two factors for each facet).

Data from the participants of all five countries were included in the regression analysis. One might ask, whether the samples from different countries can be taken together into one regression analyses (i.e. were all participants so similar in their views that no distinction can be made between geographic locations). To take this aspect into account a multi-level approach was chosen. It was first assessed whether the slopes of the regression function vary between the countries. A random coefficient model estimated with Mplus 7.1 showed that regression slopes do not differ between the countries. Therefore, it is justified to carry out the analysis for the whole sample of students from all five countries in aggregate, considering the clustered structure of the data by adding the country of origin as cluster variable.

The regression analysis (Table 4) for the factor “innocuous applications” showed that the facet "control over risk" (facet 6) had the strongest influence on whether it is ethically justifiable to further develop the technical applications. Altogether, five of the seven facets influence subjects' opinion if it is justifiable to further develop innocous applications of nanotechnology (probability of health damage, worries about risk, voluntariness of risk, knowledge of risk, and control over risk).

[INSERT TABLE 4 ABOUT HERE]

The results show positive β-weights for three variables. They mean that if the probability of health damage is low an application can be developed. If users can control whether to take the risk (voluntariness of risk) and/or when the risk is controllable an application also can be developed. Two variables obtain a negative β-weight: When people know about the risks of an application it is more justifiable to develop it further than when the risk is not known or cannot be assessed. A more puzzling results occurs with the variable “worries about risk”. When worries are stronger it is more justifiable to further develop an innocuous application. It might be, that innocuous applications are regarded as being more or less harmless and that the development is justifiable even in case of worries about the risk. The further development of the application might even allow participants to percieve that they could gain knowledge about the risk.

The regression analysis for the factor “direct contact applications” showed three facets that contributed to the assessment whether it is justifiable to further develop the technical applications: Facet 3 (voluntariness of risk), facet 7 (trust in governmental agencies) and especially facet 6 (control over risk) contribute to the opinion that it is ethically justifiable to further develop an application.

All β-weights are positive. This means if users can control whether to take the risk (voluntariness of risk) and/or when the risk is controllable and if one trusts the government that it will take responsibility for protecting people’s health, one could further develop an application.

Discussion

This manuscript describes a preliminary study of a small sample of postsecondary students' views of the importance of communicating technical issues and SEI of nanotechnology to the non-expert public at five cross-national universities. Nanotechnology is poised to be a particularly impactful technology in the near future and understanding individual views as well as perceptions of how information should be distributed to the general public are important considerations for both science educators and science communicators alike (Gaskell et al., 2004). As there are also numerous ethical considerations that must be addressed with the adoption of these technologies (Kjolberg & Wickson, 2007; Sandler, 2009), we examined the impact of these considerations on participants' views of the risks, benefits, and role of communicators in discussing nanotechnology with non-scientists. We discuss our findings within the context of the limited sample from which this study is drawn and hope that future studies will be able to replicate these findings with both qualitative and quantitative analyses.

Mapping Differences between Countries

Emerging issues in science and technology will be increasingly global in nature, and our sample consisted of students from five different internationally regional settings. Results demonstrated some differences in perceptions between these participants based on their university location. The following bullets summarize the major differences uncovered in this study in participants' views of the role of nanotechnology communication in society by country and summarize the results of research questions one and two.

- *Austria*: Participants felt that the government and nanotechnologists should only play a moderate role in communicating the technical and SEI aspects of nanotechnology. They had low levels of concern for nanotechnology.
- *Finland*: Participants felt that the government and nanotechnologists should only play a moderate role in communicating the technical and SEI aspects of nanotechnology. They highlighted the need to be competitive in global economy and had low levels of concern for nanotechnology applications.
- *France*: Participants felt that the government and nanotechnologists should only play a moderate role in communicating the technical and SEI aspects of nanotechnology. In addition they had moderate level of concern for the ethical justifiability of applications.
- *Israel*: Participants felt that the government and nanotechnologists should play a minimal role in communicating the technical and SEI aspects of nanotechnology. They had the lowest levels of concern for the ethical justifiability of applications.

- *United States*: Participants felt very strongly that the government should play a role in communicating the technical aspects of nanotechnology with nanotechnologists playing a minimal role in communicating both technical and SEI aspects. In addition, they had moderate levels of concern for the ethical justifiability applications.

Results indicated that postsecondary students from different samples may hold different views of the role of science communication for nanotechnology. Participants at the Universities in Austria, Finland and France were largely similar in their responses to the role of scientists and engineers in communication training in that they thought that both the government and nanotechnologists should play equally moderate roles in the communication of technology and SEI to the non-science public. However, postsecondary participants in France had a much higher concern for the ethical implications of the development of nanotechnology (on par with that of the United States) than either Austria or Finland. Israeli participants reported that the role of science communicator should not rest with the government or nanotechnologists, but it is not clear from our results where Israeli participants think that this responsibility should rest. Conversely, Israeli participants had very low levels of concern about the ethical justifiability of nanotechnology applications, which was the polar opposite of the United States. One interpretation of this result is that our sample of Israeli students may perceive a greater need to develop nanotechnology quickly and the priority may be on development and not on regulation related to risks.

The ethical concern for nanotechnology mirrors other work conducted on an international scale by Scheufele and colleagues (2009) who compared the “moral acceptability” of nanotechnology and found that when comparing Austria, Finland, France, and Israel, agreement to the moral acceptability was ranked in the following ways: *Finland 60 % agreement > Israel 47 % > France 44 % agreement > Austria 35 % agreement* which appears to agree with our data. Scheufele et al. (2009) correlated these views to an inherent religiosity scale of each nationality with the United States being particularly high on the scale and countries like Finland being relatively low. Other researchers have highlighted the role that cultural values play in the perceptions of emerging technologies (Priest, 2006). Although respondents in our study do not represent the countries’ general populations, to some extent the results cohere with polls on public attitudes towards science and technological progress. For instance, in Finland the general trust in science is remarkably high (Finnish Society for Scientific Information, 2013) which may be reflected in the students’ views as well.

The fact remains that there is little known about the landscape of regional and cultural differences that drive views of science and technology (Priest, 2006). One aspect that is emerging is that when ethics and morals regarding technologies are considered, religiosity of a particular culture may play a large role in its adoption and perceived acceptance of future research and development (Kjolberg & Wickson, 2007; Scheufele et al., 2009). More importantly to this study, little is known about the cultural differences that drive both scientists' and engineers' views of the importance of communicating this technology to the general public. The above results might also provide an avenue or theoretical foundation for future research regarding the connection between views of the ethical justifiability of nanotechnology development and the views of the responsibility of communication with three unique country conditions.

Understanding Influence on Perceptions and Communication

The following section examines the results from research question three. This study also reinforces the careful consideration that needs to be paid to the specific application being considered when examining students' perceptions of both ethics of emerging technologies as well as their views regarding the communication of those technologies (Authors, 2010; Ekli & Sahin, 2010; Nerlich et al., 2007). The body of research regarding science communication conducted in biotechnology would be strengthened by a more careful examination of cultural differences (Edmonston & Dawson, 2013; Edmonston et al., 2010a; Edmonston et al., 2010b). As found in this study, postsecondary participant developing scientists and engineers reported the need to take on more responsibility for the considerations of what we are calling "innocuous applications," noting that the ethical justifiability should be driven by low risk and low government responsibility for regulation. The participants also noted the need to consider the uncertainty of the risks associated with the applications. This is in contrast to the "direct contact" applications that postsecondary students felt were ethically justifiable when there was low risk, risk acceptance was voluntary, and when the government was responsible for regulating the technology. Uncertainty also plays a key role as a predictor of this perception.

When there were applications that had contested moral or ethical issues, the postsecondary students indicated that the scientists and engineers had less responsibility to communicate these issues. The data suggest that postsecondary scientists and engineers placed more importance on the communication of the science and technology of nanotechnology and were less comfortable with the role of scientists and engineers communicating the SEI because they do not perceive these issues as their responsibility to negotiate or communicate.

Conclusions and Implications

Data from previous studies imply that postsecondary students in science and engineering fields in several representative countries do not have the opportunity or the desire to participate in science communication training in their formalized schooling (Baram-Tsabar & Lewestein, 2013). It seems that many participants do not value of this training in their future careers and believe the responsibility of public science communication lies elsewhere. We argue in the introduction of this manuscript that curricular considerations are important in light of a changing perspective on science communication and its integration with formal science education. This study found contrasting views of participants from countries where science communication is seen as important to scientists and engineers (Austria, Finland, France) as opposed to those students from countries that do not (Israel, United States). Educators that work in global sectors may need to recognize and build on these contextual challenges and design targeted interventions that are sensitive to the differing views of various postsecondary populations (Baram-Tsabari & Lewestein, 2013; Mulder et al., 2008).

For example, within a French context, Simonneaux et al. (2013) have explored using a Socially Acute Question (akin to a socio-scientific issue) to stimulate student discussion regarding issues in nanotechnology and found that polarization of student argumentation is common. Other researchers have examined ways in which to teach complex SEI of nanotechnology through science fiction (Berne & Schummer, 2005). There have been efforts to integrate education as to the ethical and risk/benefit impacts of science and engineering into formal educational settings (Hoover et al., 2009) as well as to engage scientists and engineers in science communication training in real-world informal settings (Webb et al., 2012). The fact remains that both 'inservice' and 'preservice' scientists and engineers see little value in the ability to communicate their findings to the general public and often have little concern for the perceptions of the ethical impacts of their work, although data is limited and varied (Besley, Kramer, & Priest, 2008; McGinn, 2008; Toth et al., 2011a).

There is enormous potential for pre- and in-service science teachers to communicate the importance of ethical considerations to future scientists and engineers (Toth, Graham, Trythall, & Witherspoon, 2011b). But there are challenges to appropriately prepare teachers to understand the content of nanotechnology. Furthermore, many teachers share similar risk and ethical perceptions as the broader public sphere (Ekli & Sahin, 2010; Kim & Hong, 2010). Nonetheless, science teachers are charged with teaching communication as a critical component of science process skills and teaching students about the role of science and technology as human endeavours as a component of the nature of science (NGSS Lead States, 2013; Padilla, 1990).

At the postsecondary level a particularly difficult challenge to changing the curriculum to include communication and ethics rests with the need to convince science and engineering faculty of the utility of science communication within the context of student professional education. Unlike many K-12 settings which are driven by top-down policy, curriculum change and redesign often occurs from the bottom-up in university settings. How can we help faculty see the benefit of this training while also assisting them in moving away from a deficit model of thinking (Besley & Tanner, 2011; Edmonston & Dawson, 2013)?

Research into appropriate curriculum development and scientists and engineering development of science communication competency is extremely limited and needed at all levels (Trench & Miller, 2012). Explication of specific modules in the literature and their impact are needed (Yeoman et al., 2011). Our data demonstrate the complexity of curricular design that may need to occur in that cultural norms and considerations of SEI play a role in situated understandings of the role of science communication. One of the most important conceptual changes that may have to occur with scientists and engineers is that, it “sounds obvious, but I feel that scientist sometimes forget that there is more to a talk than just stating the facts” (participant SJP from Whittington et al., 2014).

References

Authors. (2009). White Paper sponsored by the National Nanotechnology Initiative.

Authors. (2010). International Journal of Science Education.

Authors. (2014). Journal of Nano Education.

Authors. (2015). Nanotechnology Reviews.

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. Public Understanding of Science, 17, 35-54. doi: http://dx.doi.org/10.1177/0963662506070159

Bainbridge, W.S. (2002). Public attitudes toward nanotechnology. Journal of Nanoparticle Research, 4, 561-570. doi: http://dx.doi.org/10.1023/A:1022805516652

Baram-Tsabari, A., & Osborne, J. (2015). Bridging science education and science communication research. Journal of Research in Science Teaching, 52(2), 135-144.

Baram-Tsabari, A., & Lewenstein, B.V. (2013). An instrument for assessing scientists' skills in public communication of science. Science Communication, 35(1), 56-85. doi: http://dx.doi.org/10.1177/1075547012440634

Berne, R., & Schummer, J. (2005). Teaching social and ethical implications of nanotechnology to engineering students through science fiction. Bulletin of Science, Technology, and Society, 25(6), 459-468. doi: http://dx.doi.org/10.1177/0270467605283048

Besley, J.C., & Tanner, A.H. (2011). What science communication scholars think about training scientists to communicate. Science Communication, 33(2), 239-263. doi: http://dx.doi.org/10.1177/1075547010386972

Besley, J. C., Kramer, V. L., & Priest, S. H. (2008). Expert opinion on nanotechnology: Risks, benefits, and regulation. Journal of Nanoparticle Research, 10, 549-558. doi: http://dx.doi.org/10.1007/s11051-007-9323-6

Besley, J. C., Dudo, A., & Storksdieck, M. (2015). Scientists' views about communication training. Journal of Research in Science Teaching, 52(2), 199-220.

Brownsword, R. (2009). Nanoethics: Old wine, new bottles? Journal of Consumer Policy, 32(4), 355-379. doi: http://dx.doi.org/10.1007/s10603-009-9100-2

Cacciatore, M.A., Scheufele, D.A., & Corley, E.A. (2011). From enabling technology to applications: The evolution of risk perceptions about nanotechnology. Public Understanding of Science, 20(3), 385-404. doi: http://dx.doi.org/10.1080/21548455.2013.793433

Edmonston, J.E., & Dawson, V. (2013, early online release). Perspectives of science communication training held by lecturers of biotechnology and science communication. International Journal of Science Education, Part B.

Edmonston, J.E., Dawson, V., & Schibeci, R. (2010a). Postsecondary biotechnology students' views of science communication. International Journal of Science Communication, 32(18), 2451-2474. doi: http://dx.doi.org/10.1080/09500690903514598

Edmonston, J.E., Dawson, V., & Schibeci, R. (2010b). Are students prepared to communicate? A case study of an Australian degree course in biotechnology. International Journal of Mathematics and Science Education, 8(6), 1091-1108. doi: http://dx.doi.org/10.1007/s10763-010-9234-3

Ekli, E., & Sahin, N. (2010). Science teachers and teacher candidates' basic knowledge, opinions and risk perceptions about nanotechnology. Procedia Social and Behavioral Sciences, 2, 2667-2670. doi: http://dx.doi.org/10.1016/j.sbspro.2010.03.392

Englander, O., & Kim, A. (2011). Nanocore at the FAMU-FSU College of Engineering: Program overview and unique assessment approach. Proceedings of the ASME 2011 International Conference.

Feinstein, N. (2015). Education, communication, and science in the public sphere. Journal of Research in Science Teaching, 52(2), 145-163.

Feinstein, N. (2011). Salvaging science literacy. Science Education, 95(1), 168-185. doi: http://dx.doi.org/10.1002/sce.20414

Finnish Society for Scientific Information (FSSI). (2013). Summary of the Finnish Science Barometer. Retrieved from http://www.tieteentiedotus.fi/files/Sciencebarometer_2013_netsummary.pdf.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Sciences, 9, 127–152.

Gaskelll, G., Eyck, T. T., Jackson, J., & Veltri, G. (2004). Public attitudes to nanotech in Europe and the United States. Nature Materials, 3, 496. doi: http://dx.doi.org/10.1038/nmat1181

Grunwald, A. (2005). Nanotechnology – A new field of ethical inquiry? Science and Engineering Ethics, 11, 187-201. doi: http://dx.doi.org/10.1007/s11948-005-0041-0

Guston, D., & Sarewitz, D. (2002). Real-time technology assessment. Technology in Society, 24, 93-109. doi: http://dx.doi.org/10.1016/S0160-791X(01)00047-1

Herkert, J. (2010). Engineering ethics education in the USA: Content, pedagogy and curriculum. European Journal of Engineering Education, 25(4), 303-313.doi: http://dx.doi.org/10.1080/03043790050200340

Hisschemöller, M. & Midden, C.J.H. (1999). Improving the usability of research on the public perception of science and technology for policy-making. Public Understanding of Science, 8, 17-33. doi: http://dx.doi.org/10.1088/0963-6625/8/1/002

Hoover, E., Brown, P, Averick, M., Kane, A., & Hurt, R. (2009). Teaching small and thinking large: Effects of including social and ethical implications in an interdisciplinary nanotechnology course. Journal of Nano Education, 1(1), 86-95. doi: http://dx.doi.org/10.1166/jne.2009.013

Irwin, A. (2009). Moving forward or in circles? Science communication and science governance in an age of innovation. In R. Holliman, L, Whitelegg, E. Scanlon, S. Smidt, & J. Thomas (Eds.), Investigating science communication in the information age: Implications for public engagement and popular media (pp. 3-17). Oxford, UK: Oxford University Press.

Johnston, S., McGregor, H., & Taylor, E. (2010). Practice-focused ethics in Australian engineering. European Journal of Engineering Education, 25(4), 315-324. doi: http://dx.doi.org/10.1080/03043790050200359

Kaplan, D. (2009). Structural equation modelling. Los Angeles, CA: Sage.

Kim, H.-J., & Hong, H.-G. (2010). Science teachers' perceptions and attitudes toward nanotechnology. Journal of the Korean Chemical Society, 54(5), 633-642.

Kjolberg, K., & Wickson, F. (2007). Social and ethical interactions with nano: Mapping the early literature. NanoEthics, 1, 89-104. doi: http://dx.doi.org/10.1007/s11569-007-0011-x

Lin, S.-F., Lin, H.-S., & Wu, Y.-Y. (2013). Validation and exploration of instruments for assessing public knowledge and attitudes toward nanotechnology. Journal of Science Education and Technology, 22(4), 548-559. doi: http://dx.doi.org/10.1007/s10956-012-9413-9

Macoubrie, J. (2006). Nanotechnology: Public concerns, reasoning and trust in government. Public Understanding of Science, 15, 221-241. doi: http://dx.doi.org/10.1177/0963662506056993

Martin-Sempere, M.J., Garzon-Garcia, B., & Rey-Roca, J. (2008). Scientists' motivation to communicate science and technology to the public: Surveying participants at the Madrid Science Fair. Public Understanding of Science, 17, 349-367. doi: http://dx.doi.org/10.1177/0963662506067660

McGinn, R. (2008). Ethics and nanotechnology: Views of nanotechnology researchers. NanoEthics, 2, 101-131. doi: http://dx.doi.org/10.1007/s11569-008-0040-0

Miller, J.D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. Public Understanding of Science, 13, 273-294. doi: http://dx.doi.org/10.1177/0963662504044908

Moor, J. & Weckert, J. (2004). Nanoethics: Assessing the nanoethics from an ethical point of view. In D. Baird, A. Nordmann, & J. Schummer. (Eds.), Discovering the nanoscale (pp. 301-309). Amsterdam: IOS Press.

Mulder, H., Longnecker, N., & Davis, L. (2008). The state of science communication programs at universities around the world. Science Communication, 30(2), 277-287. doi: http://dx.doi.org/10.1177/1075547008324878

National Science Foundation/Department of Commerce (NSF/DOC). (2002). Converging technologies for improving human performance: Nanotechnology, biotechnology, information technology and cognitive science. Arlington, VA: National Science Foundation.

Next Generation Science Standards Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC. The National Academies Press.

Nerlich, B., Clarke, D.D., & Ulph, F. (2007). Risks and benefits of nanotechnology: How young adults perceive possible advances in nanomedicine compared with conventional treatments. Health, Risk and Society, 9(2), 159-171. doi: http://dx.doi.org/10.1080/13698570701306856

Ogawa, M. (2011). A new age of cooperation and collaboration between school science education research and science communication research. International Journal of Science Education Part B, 1(1), 9-11.

Padilla, M. J. (1990). Science process skills. National Association of Research in Science Teaching Publication: Research Matters – To the Science Teacher (9004).

Patterson, T.E. (2007). Young people and news. Report published for the Joan Shorenstein Center on the Press, Politics and Public Policy. Harvard, MS: John F. Kennedy School of Government, Harvard University.

Pew Research Center for the People & the Press (2009). Public praises science; scientists fault public, media: Scientific achievements less prominent than a decade ago. Retrieved from http://www.people-press.org/2009/07/09/public-praises-science-scientists-fault-public-media/

President's Council of Advisors on Science and Technology (PCAST). (2012). Engage to excel: Producing an one million additional college graduates with degrees in science, technology, engineering, and mathematics. Retrieved from http://files.eric.ed.gov/fulltext/ED541511.pdf

Priest, S. (2006). The North American opinion climate for nanotechnology and its products: Opportunities and challenges. Journal of Nanoparticle Research, 8, 563-568. doi: http://dx.doi.org/10.1007/s11051-005-9060-7

Riechard, D.E., & Peterson, S.J. (1998). Perception of environmental risk related to gender, community, socioeconomic status, age, and locus of control. Journal of Environmental Education, 30(1), 11-19. doi: http://dx.doi.org/10.1080/00958969809601858

Resnick, D.B. (2011). Scientific research and the public trust. Science and Engineering Ethics, 17(3), 399-409. doi: http://dx.doi.org/10.1007/s11948-010-9210-x

Robinson, W.L. (2004). Nano-Ethics. In D. Baird, A. Nordmann, & J. Schummer. (Eds.), Discovering the nanoscale (pp. 285-299). Amsterdam: IOS Press.

Sandler, Ronald. (2009). Nanotechnology: The Social and Ethical Issues. Technical Report. Woodrow Wilson International Center for Scholars, Project on Emerging Technologies.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. Risk Analysis, 24, 1298-1299. doi: http://dx.doi.org/10.1111/j.0272-4332.2004.00526.x

Scheufele, D.A. & Lewenstein, B.V. (2005). The public and nanotechnology: How citizens make sense of emerging technologies. Journal of Nanoparticle Research, 7, 659-667. doi: http://dx.doi.org/10.1007/s11051-005-7526-2

Scheufele, D.A., Corley, E.A., Shih, T.-J., Dalrymple, K.E., & Ho, S.S. (2009). Religious beliefs and public attitudes toward nanotechnology in Europe and the United States. Nature Nanotechnology, 4, 91-94. doi: y

Schuler, E. (2004). Perception of risks and nanotechnology. In D. Baird, A. Nordmann, & J. Schummer (Eds.), Discovering the nanoscale (pp. 279-284). Amsterdam: IOS Press.

Secken, N. (2009). Attitude scales toward nanotechnology for chemistry teachers. Journal of Baltic Science Education, 8(3), 157-171.

Siegrist, M., Keller, C., Kastenholz, H,, Frey, S., & Wiek, A. (2007). Laypeople's and experts' perception of nanotechnology hazards. Risk Analysis, 27(1), 59-69. doi: y

Siegrist, M. (2010). Predicting the future: Review of public perceptions studies of nanotechnology. Human and Ecological Risk Assessment, 16(4), 837-846. doi: y

Simonneaux, L., Panissal, N., & Brossais, E. (2013). Students' perceptions of risk about nanotechnology after an SAQ teaching strategy. International Journal of Science Education, 35(14), 2376-2406. doi: http://dx.doi.org/10.1080/09500693.2011.635164

Sjöberg, L. (2002). Attitudes toward technology and risk: Going beyond what is immediately given. Policy Sciences, 35, 379-400. doi: http://dx.doi.org/10.1023/A:1021354900928

Slovic, P. (1987). Perception of risk. Science, 236, 280-285. doi: http://dx.doi.org/10.1126/science.3563507

Toth, E. E., Jackson, K. J., & Witherspoon, B. (2011a, April). Preparing future scientists and engineers to assess the ethical implications of their work in nano-biotechnology: Global sustainability by way of a socially aware STEM workforce. Paper presented at the National Association for Research on Science Teaching, Annual International Conference, Orlando, FL.

Toth, E. E., Graham, M. S., Trythall, J., & Witherspoon, B. (2011b, April). Nano-biotechnology literacy for sustainability in an international context. Preparing the public by educating teachers. Paper presented at the National Association for Research on Science Teaching, Annual International Conference, Orlando, FL.

Trench, B., & Miller, S. (2012). Policies and practices in supporting scientists' public communication through training. Science and Public Policy, 39, 722-731. doi: http://dx.doi.org/10.1093/scipol/scs090

Webb, A.B., Fetsch, C.R., Israel, E.I., Roman, C.M., Encarnacion, C.H., Zacks, J.M., Thoroughman, K.A., & Herzog, E.D. (2012). Training scientists in a science center improves science communication to the public. Advances in Physiology Education, 36, 72-76. doi: http://dx.doi.org/10.1152/advan.00088.2010

Whittington, C. P., Pellock, S. J., Cunningham, R. L., & Cox, J. R. (2014). Combining content and elements of communication into an upper-level biochemistry course. Biochemistry and Molecular Biology Education. doi: http://dx.doi.org/10.1002/bmb.20770

Yeoman, K.H., James, H.A., & Bowater, L. (2011). Development and evaluation of an postsecondary science communication module. Bioscience Education, 17(7). http://journals.heacademy.ac.uk/journal/beej doi: http://dx.doi.org/10.3108/beej.17.7

Zeidler, D. L. (2015). STEM Education: A deficit framework for the twenty first century? A sociocultural socioscientific response. Cultural Studies in Science Education, early online release.

Zeidler, D.L., Sadler, T.D., Simmons, M.L., & Howes, E.V. (2005). Beyond STS: A research based framework for socioscientific issues education. Science Education, 89, 357-377. doi: http://dx.doi.org/10.1002/sce.20048

Table 1

Factor solution using principle component analysis with oblimin rotation (*n* = 254) for facet eight (ethical justifiability of nanotechnologies) with factor loadings for each item and initial eigenvalues and internal consistency for each factor

	Factor 1 "innocuous applications"	Factor 2 "direct contact applications"
Clothing	.88	
Photographic paper	.83	
Car paints	.68	
Skis	.68	
Building blocks	.57	
Monitors	.51	
Car tires	.45	
Data memory	.40	
Cancer treatment		.86
Medical nanorobots		.82
Release of medications		.76
Implant coating		.76
Water sterilisation		.75
Storage of hydrogen		.62
Biosensors		.42
Food packagings		.37
Eigenvalue	1.687	6.260
Cronbach's α	.864	.830

Note: Four items were excluded from the factor analysis due to loadings on both factors.

Table 3

Descriptive statistics for each factor by country

		Austria (*n* = 63)	Finland (*n* = 35)	France (*n* = 30)	Israel (*n* = 34)	USA (*n* = 92)
Factor 1 “innocuous applications“	*M*	1.98	1.73	3.25	2.27	2.67
	SD	0.78	0.83	0.72	0.92	0.54
Factor 2 “direct contact applications“	*M*	2.20	1.76	2.96	2.11	3.09
	SD	0.82	0.60	1.02	1.01	0.61

Note: Rating scale from 1 = absolutely justifiable to 5 = not justifiable

Table 4

Results of regression analyses (β-weights) for the composite scores for the two factors on the facet "ethical justifiability of further developing nanotechnology applications" as criterion; countries have been included in the analysis as clusters (Mplus 7.1)

	Factor 1 "innocuous applications" (R^2 = .53)	Factor 2 "direct contact applications" (R^2 = .24)
	β	β
1 Probability of health damage (1 = very improbable; 5 = very probable)	.32	
2 Worries about risk (1 = not worried; 5 = very worried)	-.21	
3 Voluntariness of risk (1 = voluntary; 5 = involuntary)	.22	.23
4 Knowledge of risk to those who are exposed (1 = known precisely; 5 = not known)	-.14	
5 Adverse health effects (1 = not at all; 5 = very strong)		
6 Control over risk (1 = controllable; 5 = uncontrollable)	.51	.29
7 Trust in governmental agencies responsible for protecting people's health related to each product (1 = much trust; 5 = no trust)		.14

Note: All reported β-weights $p < .05$

Table 2

Descriptive statistics for items on students' views about the responsibilities of communicating the implications of nanotechnology research

Items		Austria (*n* = 63)	Finland (*n* = 35)	France (*n* = 30)	Israel (*n* = 34)	USA (*n* = 92)
1 How responsible should the government be for communicating the technical aspects of nanotechnology research with non-scientists? (1 = not responsible to 5 = very responsible)	*M*	3.19	3.29	3.47	3.06	4.23
	SD	1.12	1.20	1.33	1.41	1.03
2 Nanotechnologists have a responsibility to communicate the technical aspects of their research with the non-scientists. (1 = strongly disagree to 5 = strongly agree)	*M*	3.83	3.60	3.63	3.12	2.17
	SD	1.01	0.81	0.85	1.39	0.99
3 Nanotechnologists have a responsibility to communicate the ethical and social implications of their research with non-scientists. (1 = strongly disagree to 5 = strongly agree)	*M*	3.97	3.94	3.57	3.44	2.07
	SD	0.98	0.80	0.94	1.28	0.85
4. Nanotechnologists have a responsibility to communicate their research and its implications with non-scientists, but only after peer review. (1 = strongly disagree to 5 = strongly agree)	*M*	3.51	3.77	3.50	3.26	2.41
	SD	1.03	0.91	0.78	1.14	1.07